

INFRARED MAPPING OF THE DUST AROUND MAIN SEQUENCE STARS

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ABSTRACT

The photopolarimeter on ISO (ISOPHOT) has been used to investigate the dust discs around the four prototype Vega-like stars (Vega (α Lyr), β Pic, α PsA and ϵ Eri) and several main sequence stars with excess infrared emission from IRAS data. Mapping at 60 μ m and 90 μ m showed that the four prototypes were resolved, as were several candidates. High resolution linear scans were made across the discs of Vega (A0V), β Pic (A5V), HD169142 (A5Ve) and HD142666 (A8Ve). Deconvolved disc sizes, at 60 μ m are given for Vega, β Pic, and HD142666; the disc around HD169142 was not resolved at the position angle scanned. The results confirm the cool, tenuous discs around the prototypes, and show that the younger candidate stars have larger, more massive discs. Using a distance estimate of 288 pc for HD142666, the disc was calculated to have a radius of about 1100 AU, and a mass of possibly 0.01 M_{\odot} from the scan and map data.

Key words: ISO; infrared astronomy; circumstellar dust; Vega-like stars.

1. INTRODUCTION

The photopolarimeter, ISOPHOT (see Lemke et al. 1996 for information), on ISO (Kessler et al. 1996), has been used to investigate the dust discs around the four prototype Vega-like stars, Vega (α Lyr), β Pic, α PsA, ϵ Eri, (see for example Backman & Paresce (1993) for details) and several main-sequence candidate stars with excess infrared emission (from IRAS fluxes), Walker & Wolstencroft (1988). The area around the star was mapped at 60 μ m and 90 μ m to investigate the spatial extent of the dust. A new technique was developed during the ISO mission, which fully exploited the excellent pointing accuracy of ISO, and ISOPHOT made high resolution linear scans across the discs of Vega (A0V), β Pic (A5V), HD169142 (A5Ve), and HD142666 (A8Ve). Additionally, ISOPHOT was used to determine flux densities of the prototypes and candidates, from 3 μ m to 240 μ m, and observations with the low resolution

spectrometer, ISOPHOT-S (see Klaas et al. 1997 for details) gave an indication of the type of circumstellar dust, usually silicate dust, or PAH emission, or both (where the grain size is small).

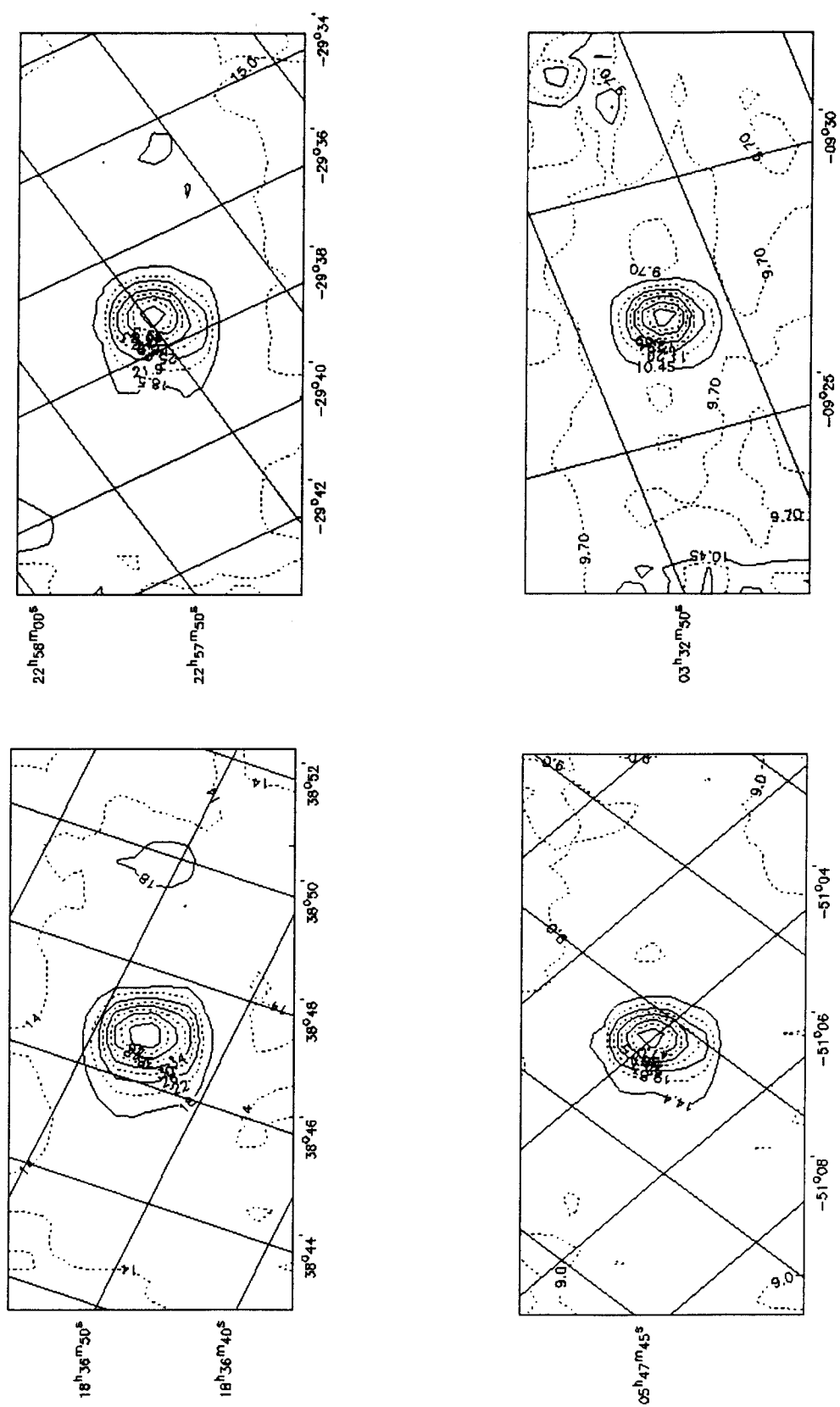
The data were reduced from the raw data stage (ERD) using PIA v7, to ensure the most recent calibration files were accessed. The maps were calibrated at the start and end of each map, and each data point was calibrated by interpolation. The 60 μ m map of HD142666 was calibrated using the orbit-dependent default responsivity, due to a premature termination of the observation (no map data were taken at 90 μ m), and the data for HD169142 were processed using the orbit-dependent default responsivity, due to saturation of the internal calibration source. HD144432 was not observed in mapping mode.

2. RESULTS

Table 1 shows whether the dust discs around the Vega-like candidates were resolved at 60 μ m and 90 μ m. Only the z-axis is considered here, and the Table gives the position angle. It is difficult to determine the sizes in the y-direction due to instrumental effects, several maps in Figure 1 and Figure 2 show a 'ghost' on the y-axis of the map due to the chopper effects. 49 Cet in Figure 2 is not resolved, and indicates the size of the beam profile at 60 μ m. The disc around ϵ Eri was resolved at 90 μ m, but only marginally resolved at 60 μ m (see Figure 1). The disc around HD142666 is very clearly elongated, and must be massive if the distance estimate is correct (288pc).

Vega was resolved at 60 μ m (Heinrichsen et al. 1997), using the high resolution linear scan, as was β Pic at 25 μ m and 60 μ m (Heinrichsen et al. 1998). HD142666 was resolved at 60 μ m, with a deconvolved disc size of 7.8 arcsec. HD169142 was not resolved at the position angle used (see Table 1).

ISOPHOT was used to obtain flux densities for the prototypes and candidates, from 3 – 240 μ m, so that the temperature and emissivity law for the cool dust emission can be determined. Many basic stellar parameters have been improved since IRAS, due to



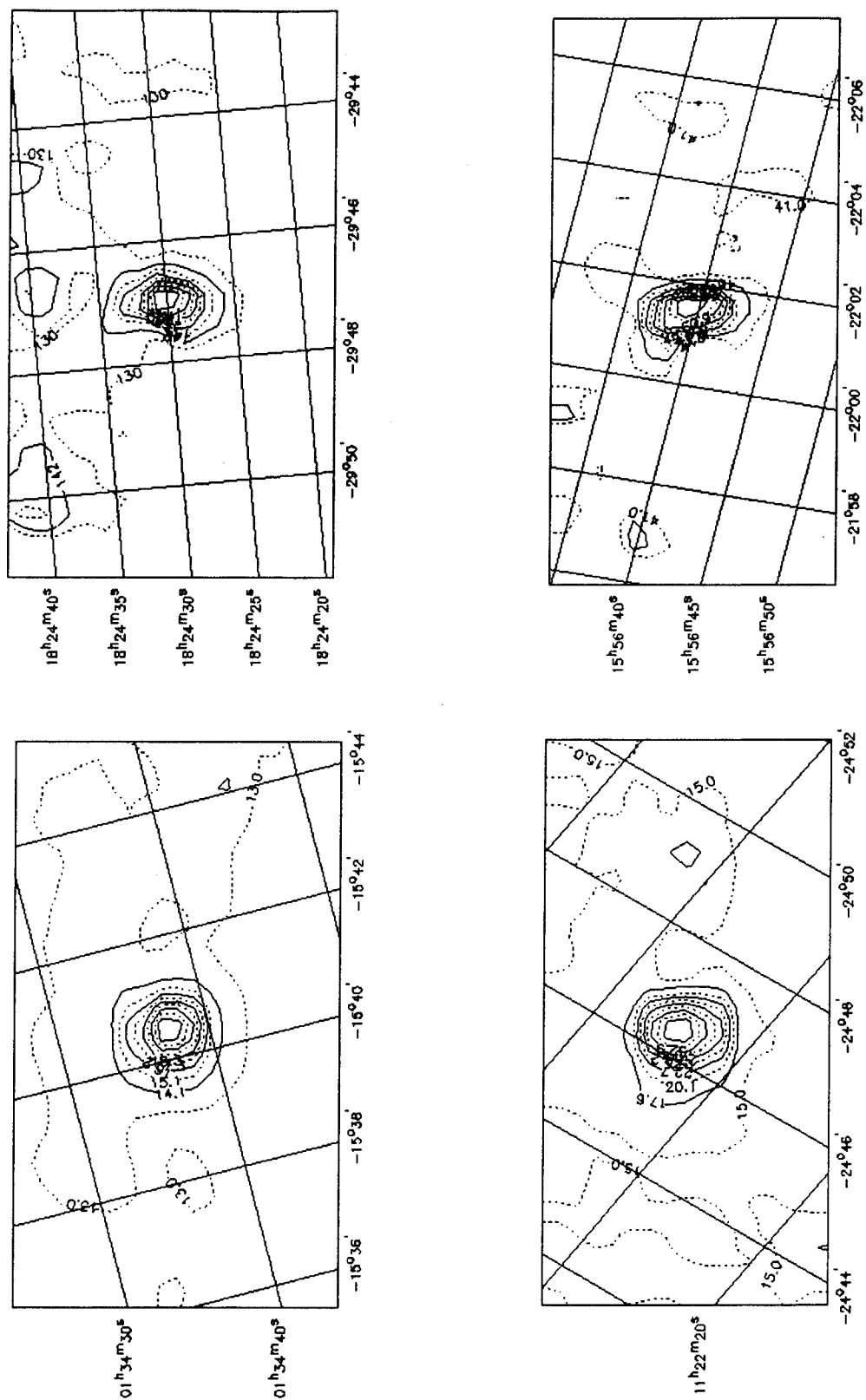


Figure 2. 60 μm maps of 49 Cet (lower left), HD98800 (lower right), HD169142 (upper left) and HD142666 (upper right).

Table 1. Dust disc sizes from the mapping and high resolution scans.

Star	D (pc)	Sp.type	spectrum (6 - 11.6 μ m)	map size 60/90 (arcsec)	z-angle (z-axis) ($^{\circ}$)	scan (60 μ m) (arcsec)	angle ($^{\circ}$)	T ($^{\circ}$ K)	emissivity λ^n
ϵ Eri	3.22	K2V	photosphere	N/27	71.8				
α PsA	7.69	A3V	photosphere	27/37	59.0			57	-1
Vega	7.76	A0V	photosphere	22/36	112.2	19	103	73	-1.1
β Pic	19.28	A5V	silicate	Y/Y	43.1	12.4	30	85	-1
HD98800	46.7	K5Ve	silicate	Y/Y	125.1				
49 Cet	61.3	A3V	photosphere	N/N	75.2				
HD34700	(76)	G0V	PAH	N/N	58.3			103	0
HD139614	(145)	A7Ve	cool dust	Y/Y	109.6				
HD144432	253	A9/F0Ve	silicate	xxxx					
HD142666	(288)	A8Ve	silicate+PAH	Y/xx	101.6	7.8	102		
HD169142	(363)	A5Ve	PAH	N/N	84.7	(4.0)	90		
HD135344	(398)	F4Ve	silicate	N/N	107.4				

The distance is that given by Hipparcos if available, or the Walker & Wolstencroft estimate in brackets. The map size (the deconvolved Gaussian width) is measured in the z-direction on the 60 μ m and 90 μ m maps, or an indication as to whether the disc is resolved in the z-direction (Y) or not (N).

The z-angle is the position angle of the z-axis relative to North in the equatorial coordinate system.

The scan (size) is the deconvolved Gaussian width at 60 μ m from the high resolution scan, where available.

The dust blackbody temperature and emissivity law are given, where they have been calculated from the ISOPHOT photometry between 60 μ m and 240 μ m.

modelling and new Hipparcos distances. These data, when combined with the spatial information, will give dust masses for the discs. The observations with the low resolution spectrometer, ISOPHOT-S, give an indication of the type of dust (usually silicate dust or PAH emission, or both) unless the grains were large (e.g. HD139614). The silicate emission feature for HD144332 is sharper than for the other stars, reminiscent of that found around certain T Tau stars.

3. SUMMARY

The disc sizes (80 - 140 AU) and masses for Vega (0.08 - 0.4 M_{moon} and Beta Pic (0.9 - 2.7 M_{moon}) were similar to those found in the submm, suggesting that they do not possess a large amount of very cold dust. HD142666 is estimated to have a disc radius of 1100AU (from the scan across the disc and the approximate distance). This leads to a dust mass of around 0.01 M_{\odot} (10 M_{jupiter}).

The results confirm the cool, tenuous discs around the Vega-like prototypes, with dust masses which are most easily expressed in terms of the lunar mass. The other stars, which are in some cases obviously younger than Vega or β Pic, have larger 'disc' sizes and larger masses, ranging up to the size of Young Stellar Object disc sizes of thousands of Astronomical Units across. Hopefully, this range of sizes/masses/ages can give some insight as to how the discs around stars like Vega dissipated as the stars grew older on the main sequence, and some insight into the era of planet formation.

ACKNOWLEDGMENTS

ISO is an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA. PIA is a joint development by the ESA Astrophysics Division and the ISOPHOT Consortium led by the Max Planck Institute of Astronomy (MPIA), with contributing institutes DIAS, RAL, AIP, MPIK, and MPIA.

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